## ART. IX.—PROGRESS IN ASTRONOMICAL DISCOVERY.

### *The Lunar Theory.*

SOME time since, Newcomb announced his discovery of an inequality in the longitude of the Moon, which had a period of 27.4 days. It can be put in the form

$$\delta v = + 1''.5 \text{ sin. } [g + 21°.6 \text{ (Y} - 1865.1)],$$

$g$ being the mean anomaly.

This term was deduced empirically from a discussion of corresponding Washington and Greenwich observations. More recently Neison of England has given an account of some lunar perturbations produced by Jupiter, and has shown that these gave rise to a new periodical term in the Moon's longitude, which could be expressed by

$$\delta v = + 1''.163 \text{ sin. } [g + 20°.85 \text{ (Y} - 1864.4)].$$

From this it follows that we have to do with a real inequality theoretically deduced by Neison in the field previously examined by Hansen and Delaunay. The agreement between the theoretical and Newcomb's empirical term is a satisfactory one. The two independent results confirm each other and dispose of the doubts expressed as to the reality of this term. It is impossible to do more than mention here the classic work of Dr. G. W. Hill, of the American Ephemeris, on the motion of the Lunar Perigee.

### *Recent Works on Double Stars.*

The lack of a comprehensive General Catalogue of Double Stars has long been a serious drawback both to the observer of double stars, and to those who occasionally desire to consult the various works on the subject. Sir John Herschel left among his papers materials for such a work, which he probably intended to be on the general plan of his excellent "Catalogue of Nebulæ and Clusters of Stars." At the time of his death data relating to about 10,000 double stars had been collected, the stars had been arranged in order of right ascension, and a synoptical history of all known observations of over 4,000 of these had been formed. It is plain that this work was intended to be most thorough, but its author did not live to finish it, and it was bequeathed to the Royal Astronomical Society and finally published by them in an incom-

plete and unsatisfactory state, as Volume XL. of their "Memoirs." Its use is chiefly that of an extended index to various double-star observations, with the approximate positions (for 1830) of these stars, and it has little or no value unless accompanied by the original works, which it was its chief object to replace.

The recently issued work of Lord Lindsay (Publications of the Dun Echt Observatory, Vol. I.) is intended to supply the place of a general catalogue so far as the double stars of W. Struve are concerned. It is a careful collection of all the measures of Struve in the "Mensuræ Micrometricæ," and in the minor works, and all these stars (above 3,000 in number) are arranged in order of their right ascensions for 1875.0. For each pair all the particulars of magnitude, color, distance, position-angle, date of observation, even the magnifying powers employed, are given, as well as the co-ordinates, right ascension and declination, for 1875. The precessions are to be taken from a table appended to the book. The full notes give further measures. Thus the particulars regarding each star are to be found collected on one line. If a reference to Struve's own measures is desired, a column gives the page of the original work where these may be found.

This volume is sure to prove useful both to observers of Double Stars and for general reference. It is capitally printed, but unfortunately quite a number of errata* still remain in the text, some even transferred from the original sources without correction. To give to this excellent work its full value these will have to be removed.

A general catalogue of double stars is now printing which will probably be found to fulfil all the conditions for a work of this class. It is from the hands of Mr. Burnham of Chicago, a distinguished discoverer of double stars, and it is the work of many years. It will contain all the elements of position (for 1880) with the particulars concerning each star from the latest trustworthy authority, and copious notes referring to previous measures. For important stars the entire history is given or rendered accessible, a special treatment having been adopted for binaries. It is to be printed as an Appendix to the Washington Astronomical Observations for 1875, and will be eagerly looked forward to by all to whom such a work is a daily need.

The Observatory at Cincinnati has begun its work, since its re-

* To take a single case. The following stars have their declinations erroneous by 4° or more: Nos. 300, 563, 635, 1012, 1062, 1714, 1806, 2008, 2036.

moval to its new site, by researches in this field. The former observations of Mitchell have been reduced and published, and also a series of measures of double stars of southern declination. It is announced by the Director, Professor Stone, that it is the plan of the observatory to observe the doubles lying in the zone between 15° and 35° S. The great number of measures made by Otto v. Struve, at Pulkova, have been reduced and printed, but no copy has yet reached the United States. Recent measures of a large number of Struve's doubles are, however, available in the work of Dunér of Lund. This includes 2,679 observations made in the nine years from 1867 to 1875. The measures were made in the manner employed by W. Struve, and are given in detail in pages 1 to 162. From page 163 to page 260 are given the measures of many of the doubles, arranged in chronological order, accompanied by a tolerably full discussion of the whole series of observations, from the elder Herschel's to Dunér's. In pages 265 and 266 is given a table in which the stars are arranged in classes according to the arc through which they have moved since the earliest observation.

Class I. contains those stars which have moved through a complete revolution, and comprises 8 stars.

Class II. those stars which have moved through 180° of their apparent orbit; 8 stars.

Class III. those which have moved through 90°; 8 stars.

Class IV. those which have moved through 30°; 16 stars.

Class V. those which have moved through 10°; 48 stars.

Class VI. those which certainly have an orbital motion; 59 stars, etc., etc. So that there are 147 stars in this list which have been proved to be binary in character.

The recent measures of Dembowski, Ferrari, Wilson and Seabroke, Hall, Newcomb, Gledhill, and others are noteworthy, as well as the theoretical researches of Doberck on binaries, but they are too numerous to be referred to in detail.

*The Great Telescopes of the Future.*

Howard Grubb, of Dublin, well known as the maker of many of the largest and most successful of the telescopes of the world, has just published a paper of great importance, giving the considerations which seem to him to indicate the direction in which important advances in the art of instrument-making are to be looked for. The paper consists mainly of a series of propositions (so to say),

each of which is separately considered. The advantages which Refracting telescopes, of such sizes as are already in existence (i. e. 26 inches in aperture and below), possess over Reflectors are first noticed.

1st. "Inasmuch as the light lost by the two reflections in case of a Reflector is greater than the amount lost by transmission through an object-glass of corresponding size, a Reflector, to be of the same optical power, must be of greater diameter than a Refractor; consequently, it will be subject to greater atmospheric disturbance, and will not be usable with as low a power as the Refractor. The light-collecting power of a unit of surface of a Reflector is independent of the size, while in a Refractor it diminishes as the size increases, on account of the extra absorption of light, from the extra thickness of glass." From experiments on various kinds of glass, Dr. Robinson, Director of the Armagh Observatory, estimates that a Refractor of 35.435 inches aperture would be just equal to a metallic Reflector of the same size, and that beyond this size the Reflector would have the advantage.

2d. The second advantage of Refractors consists in "the greater permanence of collimation and consequent suitability for ordinary observatory work, and for measuring purposes." Mr. Grubb justly remarks, that, while this advantage is a real one for the smaller sizes, and when fitness for all kinds of work is regarded, yet we must consider the large telescopes of the future in relation to *special* functions. Their field of work is limited, and no large telescope of any class can supersede the small Refractors of the size of those at Berlin, Dorpat, Leipzig, etc., for the every-day uses to which they are put.

3d. Refractors again are superior in the "permanence of the optical parts," and this, with the second instance, leads to the fourth, which relates to their superiority in "suitability for observatory work and measuring purposes." Again (from their construction),

5th. "There is no central mirror in the Refractor to disturb the course of the rays"; and further (from their construction),

6th. We have "less effect from air-currents in Refractors," since they permit of tubes closed at both ends.

Summing up the advantages which Reflectors possess over Refractors, we have,—

B[1]. "Absence of secondary spectrum." All Refractors of large size made on the ordinary forms and with the present kinds of

glass possess this defect in a large degree, and must do so. This is not harmful, however, except for bright objects, as the moon, the planets, and the brighter stars; in the largest Refractor now in use (that at Washington) it cannot be said to interfere in any considerable degree with work on the vast majority of double stars or the faint satellites of the outer planets, on nebulæ, etc. when only *micrometric measures* are considered. This Mr. Grubb does not notice, and it is an important point, as work in this field is practically unending.

$B^2$. The next point noted is the better "applicability of the Reflector for physical work," understanding by this the great problems of Celestial Photography, Photometry, Spectroscopy, etc. It is, however, to be noted again that by confining a large instrument to a *special* field great results may be still had from the Refractor. Mr. Rutherford of New York, for example, has his 13-inch Refractor so adapted to photographic work that the best lunar photographs extant have been made by its use; and this in spite of the fact that two of the finest Reflectors in the world are devoted to the same pursuit. This is another point not elaborated by Mr. Grubb.

$B^3$. The next point made by Mr. Grubb in favor of Reflectors is "the possibility of supporting them with perfect freedom from flexure irrespective of size." Here it must be said that general experience has not confirmed Mr. Grubb's proposition, as there is probably no Reflector even of the sizes now made which will stand the rapid handling to which Refractors are daily subjected. Up to twenty-six inches noxious flexure of objectives can be avoided, and there is every reason to believe that up to thirty-six inches the same immunity could be secured.

$B^4$. "The general convenience of the Reflectors for observing purposes." This consists chiefly in the short foci allowable, and constitutes a real advantage. Mr. Grubb next examines the effect of *increase of size* upon the advantages enumerated in each case; and, first, for the advantages of Refractors it is concluded that only the third advantage really becomes greater with increase of size, while most of the others are nullified or remain as before. In the effects of increase of size on the advantages of the Reflector, it is different, and (retaining the numbering just given) he finds that for $B^1$ the advantage increases rapidly with increase of size. In $B^2$ the advantage is the same, size for size, always. $B^3$ increases with the size. We have noticed the freedom from flexure of the

Washington glass, but Mr. Grubb in his own practice finds sensible flexure even in 15-inch glasses and uses three intermediate supports for these (six in all), and in the 27-inch Refractor which he is making for the Vienna observatory he expects to use six such.

This advantage of the Reflector could be reduced, however, as Mr. Grubb himself suggests, either by introducing a central support, or, more elegantly, by having an air-tight tube for the Refractor, hermetically sealed and filled with air under pressure. The eye end could be sealed by a Barlow lens of low power. This air would form the most perfect of supports for the objective, and the plan is quite feasible, though novel. Mr. Grubb has worked out the details of this plan, and finds that for an objective of forty inches aperture and six hundred pounds weight, two thirds of whose weight it is required to support by the air-cushion, a pressure of one third of a pound per square inch (one fiftieth of an atmosphere) would suffice.

B[4]. This advantage increases rapidly with increased size. With regard to the practical difficulties in each case and the most promising means of overcoming these, Mr. Grubb adduces from his own extensive experience the most important facts. For Refractors, it appears to him "that the chances of obtaining 40-inch discs of glass, in the present state of the art of glass-making, are remote." The difficulties of figuring large objectives can be overcome by the opticians without doubt. Certainly Mr. Grubb in Europe, and the Clarks of Cambridgeport, will undertake to figure an objective of any size. For Reflectors, the difficulties of getting discs of glass over six feet are probably insuperable, as no one of the glass-makers in Europe is now willing to undertake to make a disc of that diameter (although the *quality* of the glass is here of no moment), and therefore silver-on-glass Reflectors of that size are for the present out of the question. With regard to metallic specula of large dimensions Mr. Grubb says that his own experiments lead him to believe that we shall soon be able to produce metallic mirrors with a reflecting power twenty-five per cent greater than those formerly made; they certainly can now be made of six feet aperture. It is probably in this direction that Mr. Grubb looks with the greatest hope. His final conclusion, "that no one kind of telescope is *best* for all kinds of work, and that in the choice of telescopes reference must be made to the work that the instrument is intended for" and to the circumstances under which it is to be employed, is

so eminently just that it simply requires to be stated to be admitted.

*The Comets of 1877.*

The recent dearth of comets has been supplied in 1877 by the discovery of three. Comet *a* was discovered by Borelly of Marseilles, on February 8, and was visible as a telescopic object till March 18 in Europe, but was observed by the 26-inch telescope at Washington so late as March 30. It had the usual comet spectrum. Comet *b* was discovered by Winnecke of Strassburg, on April 5, and independently by Block of Odessa, on April 10. Young of Dartmouth and Wolf of Paris have investigated its spectrum, which is of the usual type. Comet *c* was discovered by Swift of Rochester on April 10, and independently by Borelly on the 14th. It was at first supposed that Comet *b*, whose elements are similar to those of 1827.II. and 1852.II., might prove to be periodic, but according to Hind this is not likely. There is a strong resemblance between the elements of Comet *c* and those of the Comet of 1762. D'Arrest's periodic comet was detected on the 30th of July by M. Tempel, of Florence.

*Astronomical Expedition to Ascension Island.*

Mr. David Gill of England is to take up his residence at Ascension Island, for the purpose of making heliometric observations of Mars to determine the solar parallax. The heliometer to be employed is the one used by Mr. Gill in the Transit-of-Venus Expedition of Lord Lindsay in 1874, in which Juno was observed and the parallax 8″.82 deduced. This expedition is of great importance in many ways, as it is quite possible that from its results the best determination of solar parallax may be had, the method employed admitting of great refinement. The support given to the expedition is also noteworthy, as the Royal Astronomical Society guarantees the expenses, £500, and as several observatories will join in the fixing of the star places, etc. It contrasts with the unfortunate expedition of Gilliss (1849 – 52), who, on his return to the United States from Chili, found that his brilliant labors in the same field, although by a different and less independent method, had been practically in vain, through the feeble support given by Northern observers.

### *The new Durchmusterung.*

Astronomers will never cease to be grateful to Argelander and his assistants, Krueger and Schoenfeld, for the *Durchmusterung des Nordlichen Gestirnten Himmels,* which embraces all the stars, of the first nine magnitudes, from the North Pole to 2° of south declination. This work was begun in 1852, and at its completion a catalogue of the approximate places of no less than 324,198 stars, with a series of excellent star-maps giving the aspect of the northern heavens for 1855, was at the service of astronomers, and has been in the most constant use from that time forward. Argelander's original plan was to carry this *Durchmusterung* as far as 23° south, so that every star visible in a small comet-seeker should be registered. His original plan was abandoned, but his former assistant and present successor at the observatory of Bonn, Dr. Schoenfeld, is now engaged in executing this important work. The same methods will be followed by Schoenfeld which were so successful formerly; the equinox of 1855 is chosen as the fundamental one; and almost the only changes are the adoption of a telescope of six inches aperture for the work, and a closer discrimination of the magnitudes of the fainter order of stars. In the prosecution of the plan, Schoenfeld has already determined the position of 74,885 stars; and astronomers in the northern hemisphere will soon possess an index, as it were, to every star likely to be used in their observations.

### *New Satellites to Mars.*

On the 16th of August, since the above was written, Professor Hall, in charge of the 26-inch equatorial of the Naval Observatory at Washington, discovered a faint satellite to Mars. From the observations up to the present date, it appears that its time of rotation is about thirty hours, and its greatest distance from the centre of Mars about eighty seconds of arc. It appears to be of the 13-14 magnitude. The mean distance of this satellite is between 14,000 and 15,000 miles, which is less than that of any known planet.

On the 18th of August Professor Hall suspected the existence of another satellite interior to the first; at the date of writing this no further observations are at hand. The discovery of these two satellites is one of the most important astronomical events of the century, being paralleled only by the discovery of Ariel and Umbriel by Lassell, and of Hyperion by Lassell and Bond.